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Study on The Process of Thin-walled Titanium Alloy Tube Bending

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Abstract

Some items of an important project are tubes which are made of Titanium alloy. The diameter of the tubes is large but the wall is thin, e.g.Φ25×0.5.The ratio of diameter to wall thickness can reach to 50. At the present time, sorbitol is used to bend this kind of tube. There are some problems need to be resolved, such as long manufacture cycle, insecure bending quality and the difficulty of controlling the quality of the cleaning after bending. The purpose of this paper is to resolve aforesaid problems and find out a kind of new technics substitute for present forming method.

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Keywords: Vector;DBB(Distance Between Bends);POB(Plane Of Bend);DOB(Degree Of Bend);bend with sorbitol;bend with mandril

1. Introduction

Bending tube with sorbitol is a kind of bending method which is introduced in a key project aircraft .In bending forming process of the large diameter and thin-wall titanium alloy tube, sorbitol is used as upholder to prevent corrugated tube wall and roundness deviation. But there are many shortcomings in the process of production, for example, long production cycle, forming instability, cleaning quality is not easy to control after formed, etc. so these lead to weak product quality and long production progress.

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2. Main body

2.1. The noun explanation

The vector: the amount which has size and direction. The directed line segment In the geometry is an intuitive vector. From the theorem of two equal in same size and same direction are equal, the vector after a parallel moving is equal to the original vector, so the starting point of the vector can be placed in any space.

DBB (Distance Between Bends) : the distance between the endpoint and the intersection point of straight line and circular arc or the distance between the straight line and the the intersection point of two circular arcs . For pipe bender, it is the sent straight line distance before bending.

POB (Plane Of Bend) : the angle between the plane of the second bending and the plane of the first bending when two bending is not in a plane, For pipe bending machine, it is the rotation angle of clamp head which holding the pipe. And clamp head can make positive rotation , also can do reverse rotation.

DOB (Degree Of Bend) : the angle between the second center line and the first center line. For pipe bender, it is the turn angle of bent arm .

Sorbitol filling: it is a common filling agent with high elasticity and good adhesion,it ensure the bending quality and the inner surface roughness of stainless steel、titanium alloy steel bending

Resilience:the metal material has a force deformation, and is bent into a point of view In the process of bending.When external forces is been revoked , the bent pipe recovery partially,the bending angle measured is smaller than the bending angle needed, the difference between the two is the resilience.

2.2. CNC bending process

CNC bending has been widely used in many aircraft manufacturing enterprises. CNC bending has many advantages which traditional bend do not have, the accuracy of CNC pipe bender is ± 0.004 inches, accumulated error of per foot is ± 0.001 inches. Angular deviation is +±0.01 degrees, repeat accuracy of ± 0.05 degrees. and it is efficient, easy to control forming ,good quality, easy to clean, no manufacture tailing, so can meet the requirements of manufacturing fully .

CNC bending process is similar to the traditional bending process, the pipe bending can be decomposed into three basic actions, namely straight feed , rotate and bend. Of course, the pipe bending also need some auxiliary motions, such as clamping die clamp, lamping die loosen, bending die reset, etc. All pipe bending actions are the combination of these simple mechanical actions in certain order, differently ,the traditional bending process relys on people to control ,but CNC pipe bending process relys on high precision gears and motor to control. Based on the theory of vector, the centre line of tube is seen as a serie of space vectors, and calculate accurately" the incremental bend data "by using the basic concepts and operations of vector, and the data can control the pipe bender. This bending can also be calibrated automatically. It calculate the "difference" by compared with standard data, correct the "difference" ,then we get the new data to bend, this is the basic characteristic of vector bending.

"The incremental bend data"include:

Nomenclature

DBB	the distance between the two bends
POB	plane of the bend
DOB	degree of bend

Every bend can be said with these data. A bend data is based on the previous data, so it is called "the incremental bend data". The data word effectively after resilience correction.

2.3. The characteristics of the CNC pipe bending

CNC pipe bender is mainly composed of lathe bed, bend head, car and core institutions.

- Bend head make lateral movement along the guide rail, and this is necessary to adjust the bending die aiming the center line of the machine after changing bending die. This is easier to adjust the center line of lathe bed.
- The car is pulled forward movement after straight feeding in the process of tube bending, so it approach to the problem of the same speed
- In the bending process, the car is seen as a load. In order to improve the bending and avoid thickness of tube bending part thinning, it increases the booster device, so there is not only stamper pressuring the pipe but also the booster pushing forward, and it has this advantage in the larger diameter pipe especially.
- The bending arm and bending spindle become an organic whole and bending mould is replaceable,this structure not only provide strength of mechanical parts but also simplify structure so that the electric circuit is simplified.

2.4. The characteristics of fill sorbitol bending

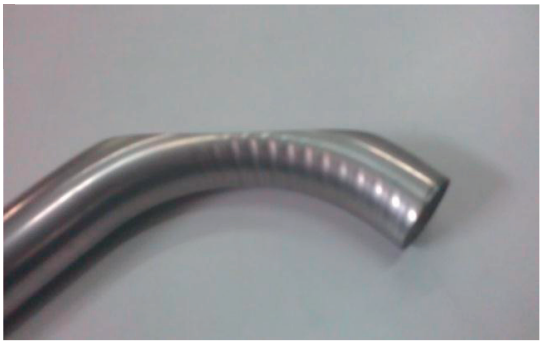
Bending tube with sorbitol is a kind of bending method which is introduced in a key project aircraft .In bending forming process of the large diameter and thin-wall titanium alloy tube, sorbitol is used as upholder to prevent corrugated tube wall and roundness deviation. But there are many shortcomings in the process of production, mainly:

1.It has a long production cycle. A single production need 3 ~ 5 days period generally, and the most of the time is being spend in melting and cleaning sorbitol, but the set-up time of ordinary CNC bending is just 3 ~ 4 hours.

2.The forming quality is not stable . Because of repeated using of sorbitol, it is easy to mixed with impurities. sorbitol shatter easily ,and it lead to a disabled molding that forming parts inside the bend ripple (figure 1).

3.it is very hard to clean inside after forming. As a general rule, we using the 70 ℃ ~ 80 ℃ hot water for soak clearing, but there are intraductal residue and dirt and they will be taken to the next working procedure.

a: b:



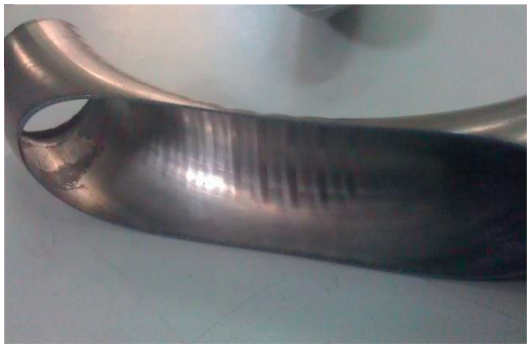


Fig1 a and b:Tube bent with sorbitol

2.5. design mandrel bending mould and adjustment machine tool

Thin-walled tube bending needs reasonable fit clearance between mould and pipe, bending parts wrinkles easily when the clearance is too large, and g bending position prone to cracking and scratching when the clearance is too small, so it is necessary to design and manufacture special mold for the thin-walled tube bending.

1.bending mould: the length of clamp which is used to clamp pipe should be greater than 2 D (D = pipe diameter), especially when they are large diameter pipes, this value should be larger in order to bend availably. Because of the elliptical features, when bending radius is small,(such as less than or equal to 2 D), the bending parts will have serious wounds, the depth of the bending mould slot should be slightly darker than Pipe radius.

2.clamp mould: it is used to clamp tube and rotate with bending die , and then the pipe will be bent into a certain angle. The width of the clamp mould should be no less than 2 to 3 times the diameter of the pipe, especially for thin

wall and large diameter pipe. If the width is too small, the clamp mould can not clip pipe bending firmly and then slippage easily.

3.stamper: in the process of bending, it press the pipe to the bending mould and lt provide a lateral pushing for the pipe. stamper pressure must be control and regulate strictly. If the pressure is not enough, the inside of bending parts wrinkles easily; If the pressure is too big, it can thin the bending parts and produce " goose head inside". When using mandril, if the pressure is too large, the front of the pipe arise deformation easily and interfere with mandrel,and that can make impossible to bend. But Insufficient pressure can also cause ovality increasing on bending parts.

4.mandrel: it is divided into common mandrel and the ball head mandrel. Mandrel is made of copper materials and has "three goals" in the end , its characteristic is its swing in any direction, this structure can support wall continuously, and reduce or eliminate corrugation Inside and outside of the pipe bend .Mandrel should be put in the position of the bending point, and the location of the point of tangency influences the ovality and springback of pipe.

Mandrel rod has enough rigidity and need to be deburred and polished carefully in order to reduce the ripple, and appropriate lubricant is set, to minimize scratch and to reduce frictional resistance. The radial clearance beteen Mandrel and pipe should be no greater than 0.15 mm.In order to guarantee right clearance, mandrel should be divided into groups in accordance with the pipe diameter .

5.crease-resistance mould: large diameter and thin wall pipe ,small bending radius in bending,you should use crease-resistance mould and mandrel. The shape of crease-resistance mould is very important. The front end of the mould should be made so thin that it can stretch to the point of tangency of bending mould,and is supported by bending mould. There should be a small taper slightly on the mould In order to reduce the bending resistance.The stamper pressure should be adjusted appropriately during the installation.

In the process of bending, crease-resistance mould should be coated with moderate oil, but it will creates wrinkles in bending parts if too much or too thick oil.

In the use of crease-resistance mould while using the ball head mandrel might be wise. Crease-resistance mould is used to prevent wrinkling in bending ; While the ball head mandrel can keep supporting the pipe after leaving mandrel strong point.

6.the adjustment of the booster: the car and stamper boost for pipe synchronously.The booster drive stamper longitudinal movement actively, and offset resistance of bending, so it can be used to prevent wall thinning too much and reduce springback.

7.the choice of lubricant: The quality and quantity of lubricant in use are very important. 20, 30oil as a lubricant is often used for traditional bending .Due to the fast bending in CNC bending, there is high friction between mandrel and pipe wall.The lubricant must form lubricating membrane infer the inner wall and mandrel.Ordinary oil cannot meet the conditions, so we can choose glycerinum to achieve the purpose of lubrication. The pipe bending machine is equipped with a mandrel lubricating device, the lubricant can be taken into the pipe inner cavity through the mandrel rod and plug the hole.

2.6. Thin-walled tube bending parameters test、determine

Compared to ordinary catheter bending,thin-walled tube bending need lower molding speed, proper boosting speed and pressure, reasonable aim of rods, the correct crease-resistance mould position and so on, these factors should be tested and verified repeatedly , ultimately obtain the appropriate molding process parameters.

After much trial and error, it is concluded that the following data:

Table1 Contrast between mandril and sorbitol

The speed ratio of mandril to sorbitl	bend radius	clearance between stampere and crease-resistance mould	inboard ripple	outboard ripple	decline of tube wall
15%	3D	1.0mm	有	无	+0.05
5%	3D	0.8mm	无	无	-0.10
5%	3D	0.8mm	无	无	-0.08

By verification of the test pieces and mass production, tube bending is qualified and has reached the expected goals and requirements (as shown in figure 2).

a: b:

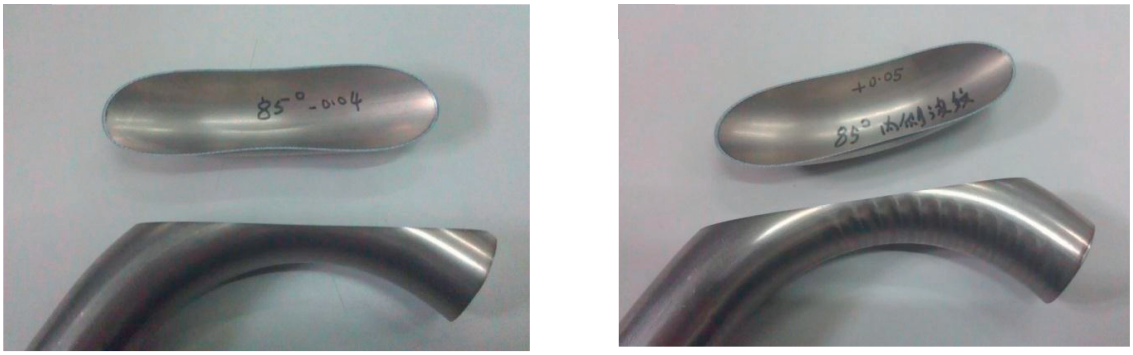


Fig2 a and b: tubes bent with mandril

3. Conclusion

Through the test and production practice, we grope and mastered the technology of thin-walled titanium alloy tube bending, solve the problems in the traditional thin-walled titanium alloy tube bending process.The practice has proved that the method we adopted the mandrel bending is scientific, the bending tool designing is reasonable. Through the use of the new technology method, it has improved product quality, saved raw materials, reduced the loss of waste, shorten the production cycle, has good popularization and application value.

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